Regional Climate Modeling Studies for California: Future Scenarios and Impacts

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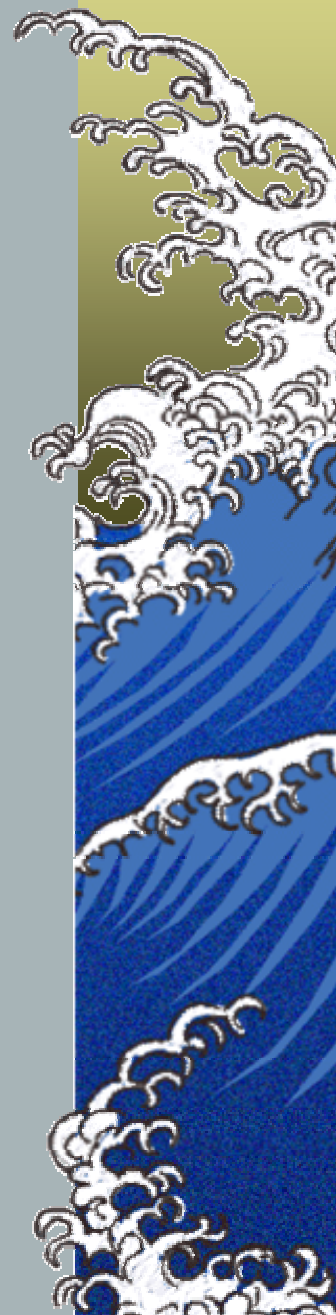
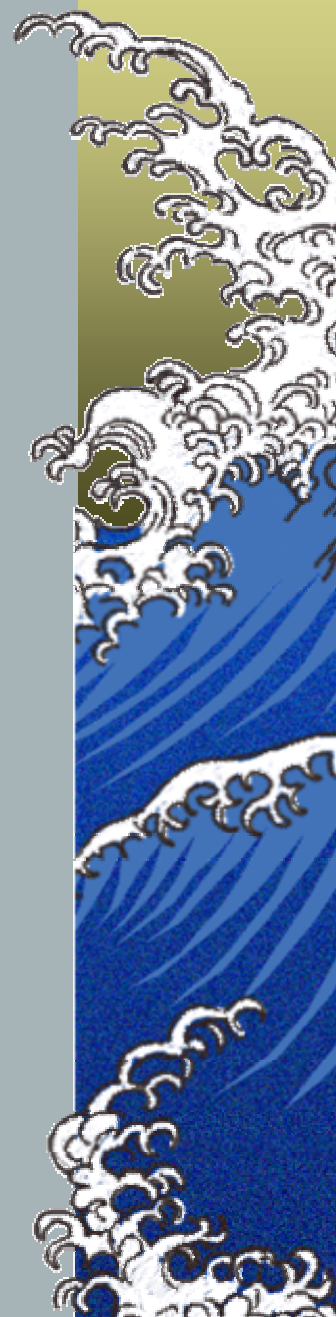
Talk Outline

- *Why study climate change?*
- *Why study climate change at a regional scale?*
- *Future climate scenarios for California and their possible impacts on various systems*

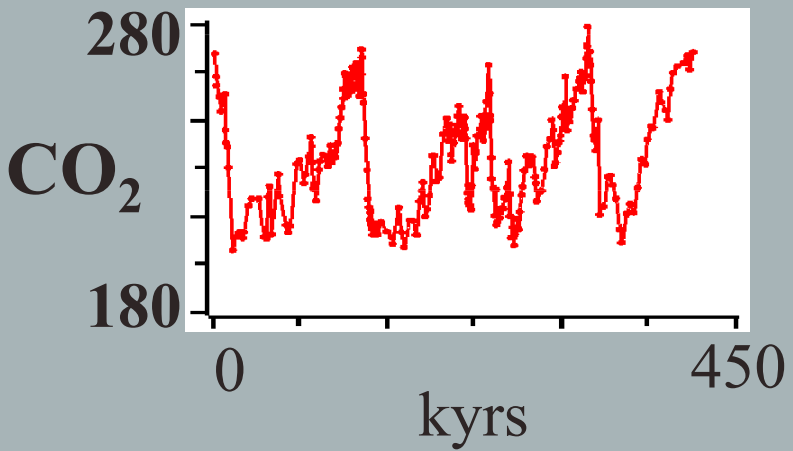


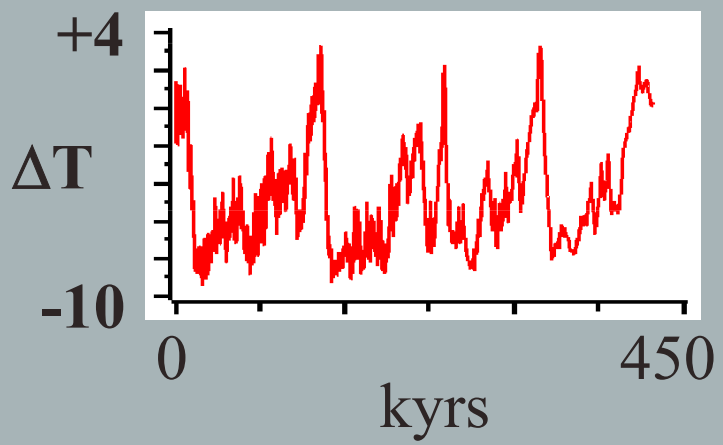
Why study climate change?

- *Climate has changed dynamically over all of earth's history, over a range of temporal and spatial scales -- without human influence*
- *Climate will continue to change; what does human influence contribute?*
- *Climate affects all physical and biological systems (and can be affected by them)*



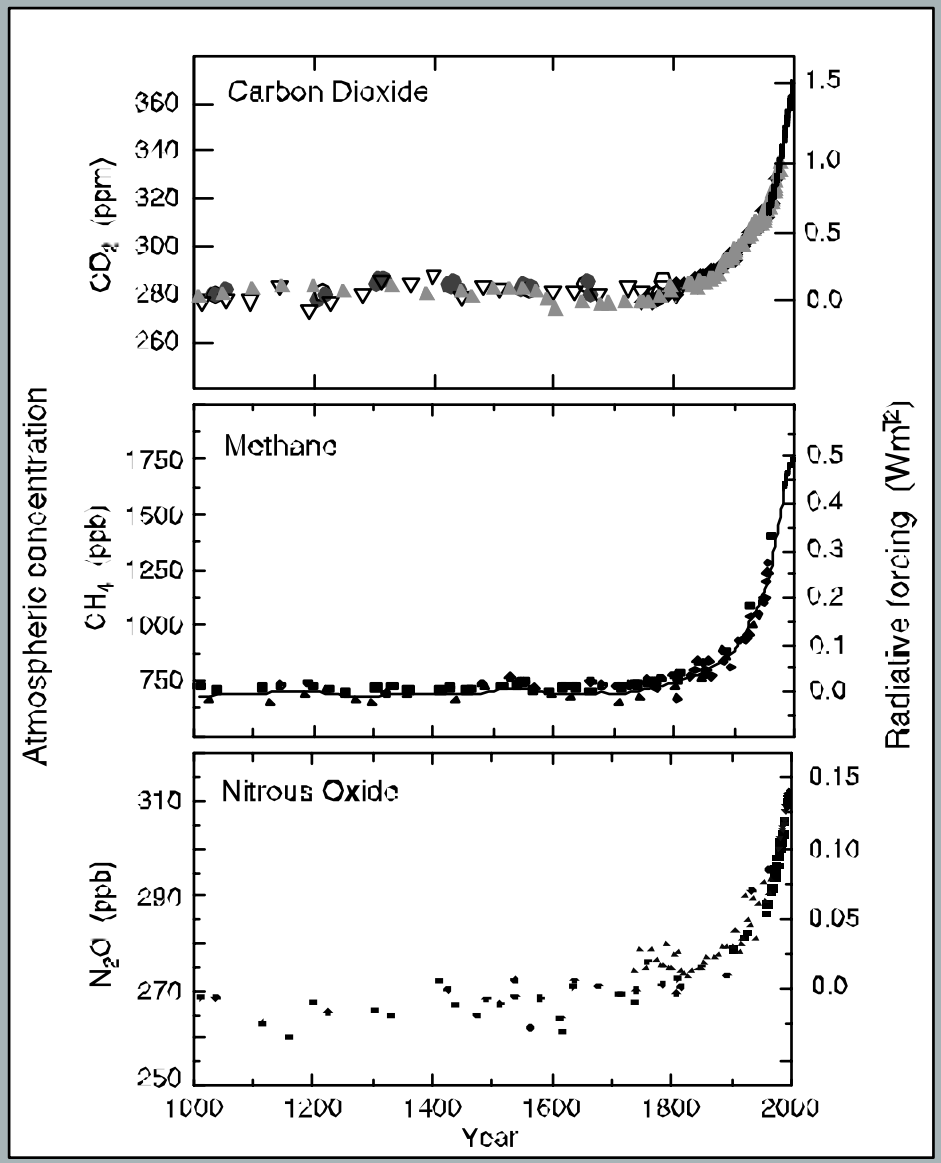
Vostok CO_2 and Temperature Records: Past 450,000 Years



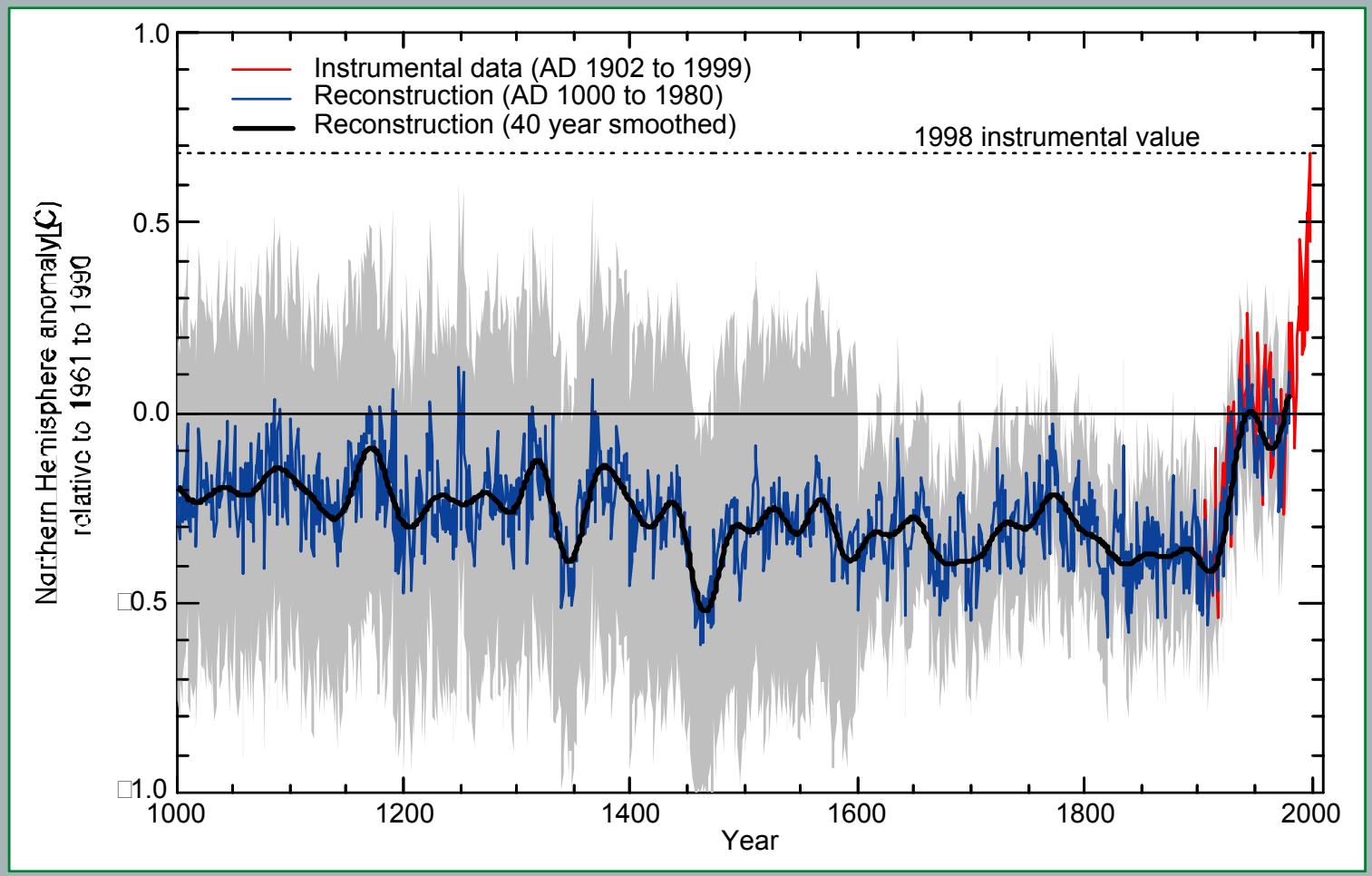


- *Ice core records from Vostok, Antarctica reveal pCO_2 and temperature variations over the past 450,000 years*

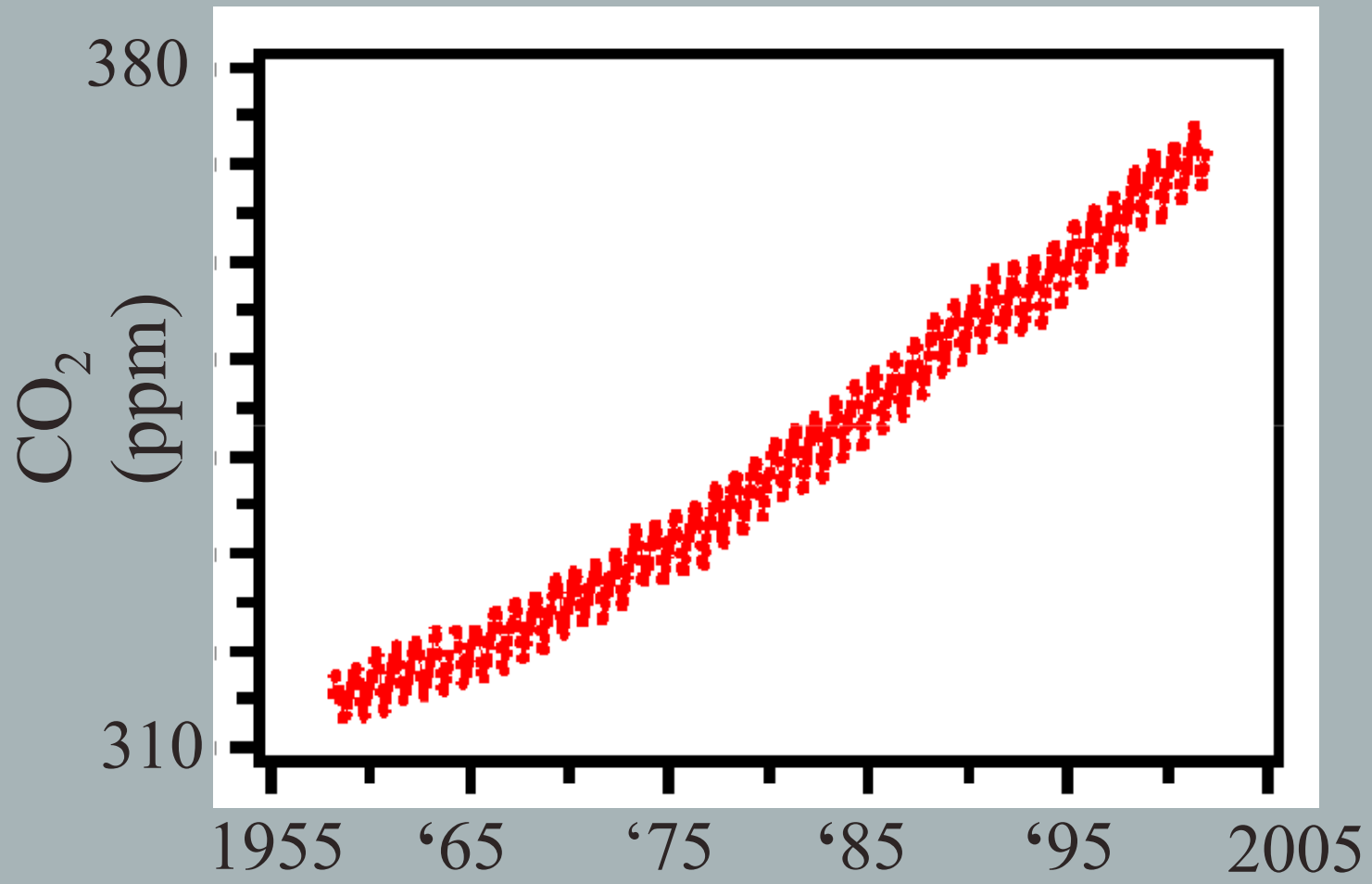
GREENHOUSE GAS CHANGES OVER the PAST 1,000 YEARS: The HUMAN FACTOR



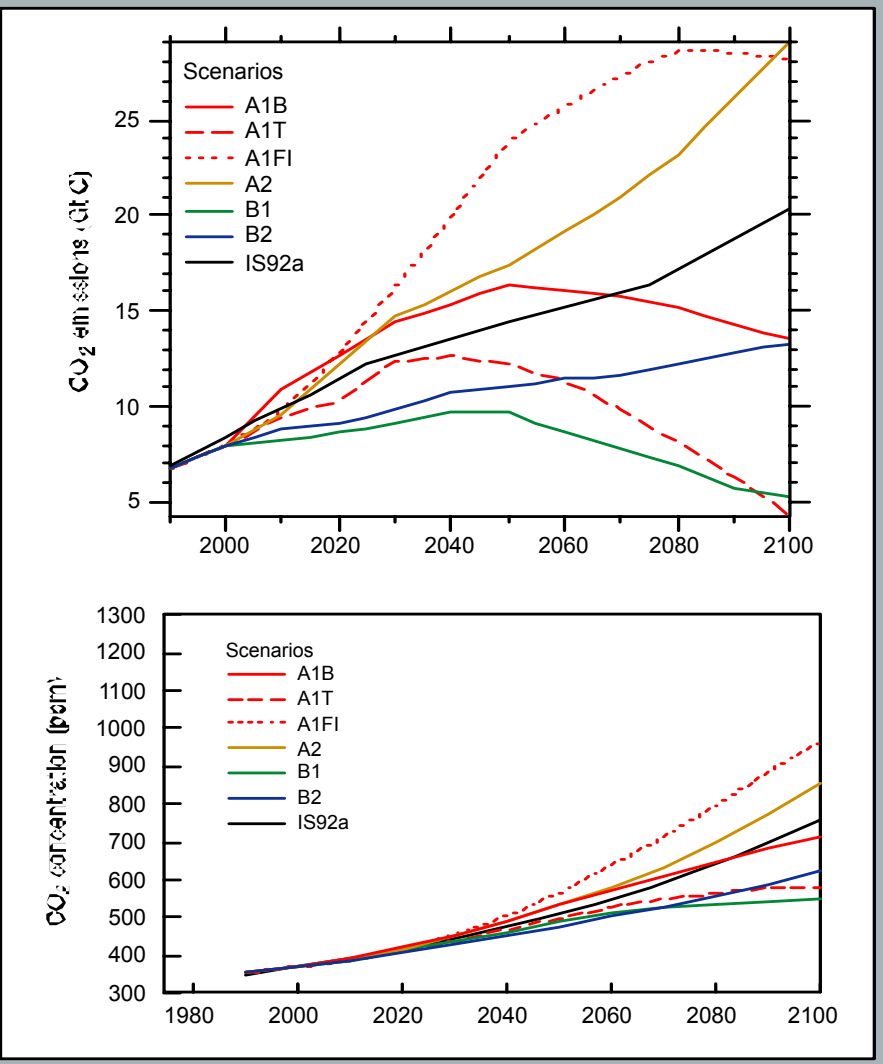
NORTHERN HEMISPHERE TEMPERATURE CHANGE from 1961-1990 AVERAGE



ATMOSPHERIC CO_2, 1958 - PRESENT



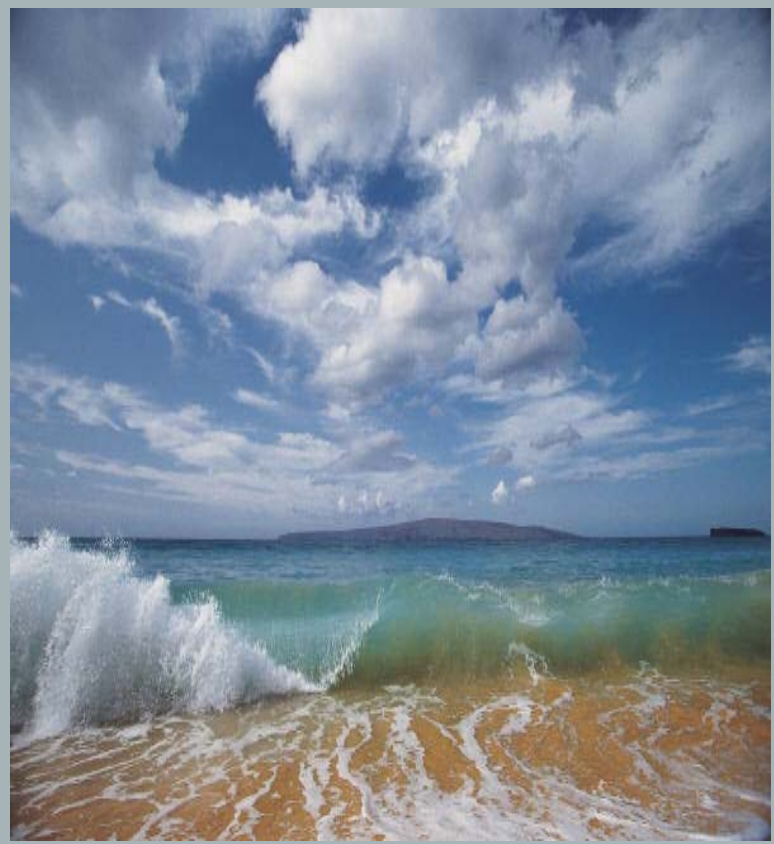
THE NEAR FUTURE for ATMOSPHERIC CO_2?



- *Estimates from the Intergovernmental Panel on Climate Change suggest that, no matter what strategies are adopted, atmospheric CO_2 concentration will reach doubled pre-industrial (1850s) levels by approximately 2050*
- *HOW WILL CLIMATE CHANGE WITH THIS CO2 INCREASE?*

OUR RESEARCH TOOLS: CLIMATE MODELS

- *Global Climate Models (GCMs) are complex 3D computer representations of Earth's climate*
- *Regional Climate Models (RCMs) are complex climate models for limited areas, and are capable of greater spatial detail than GCMs*

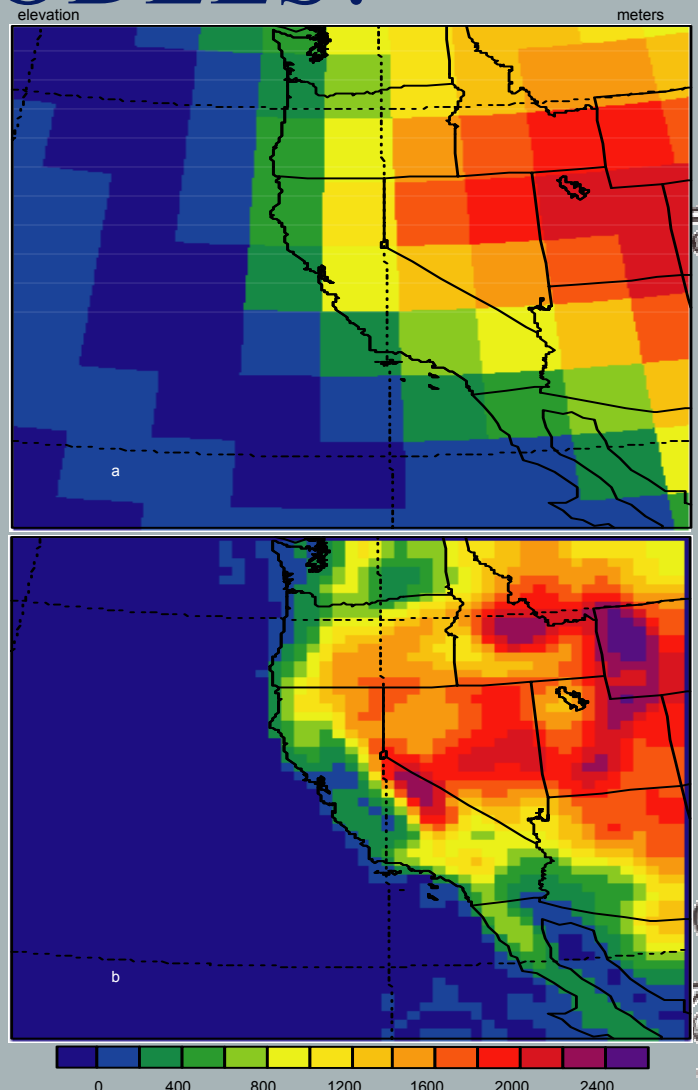


WHY USE REGIONAL CLIMATE MODELS?

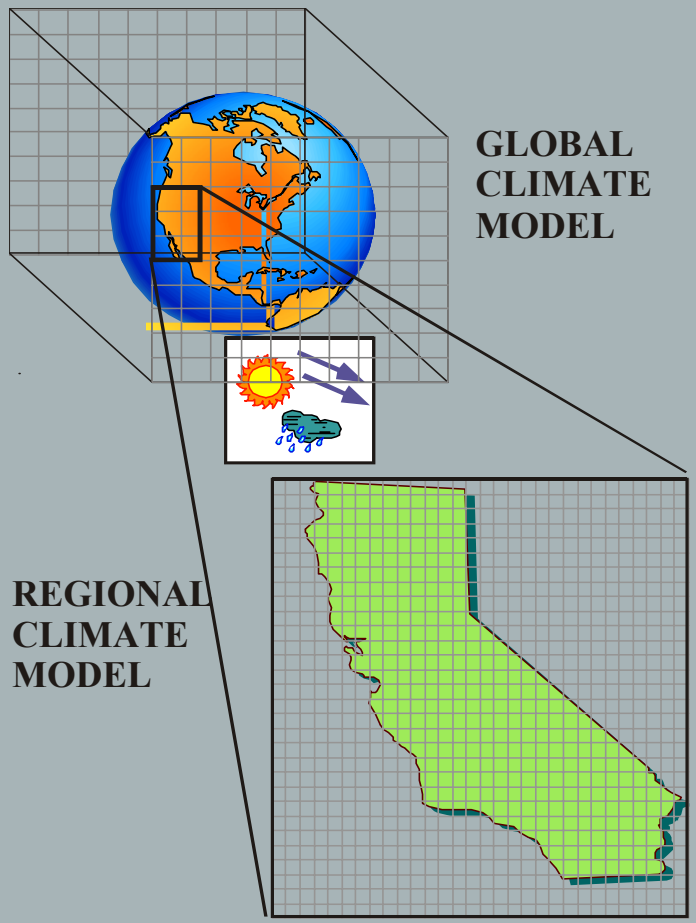
- *Regional climate models allow greater detail than is possible in global models*
- *RCM physical processes are described at more appropriate spatial scales than in GCMs*

GCM (300 Km gridpt side)

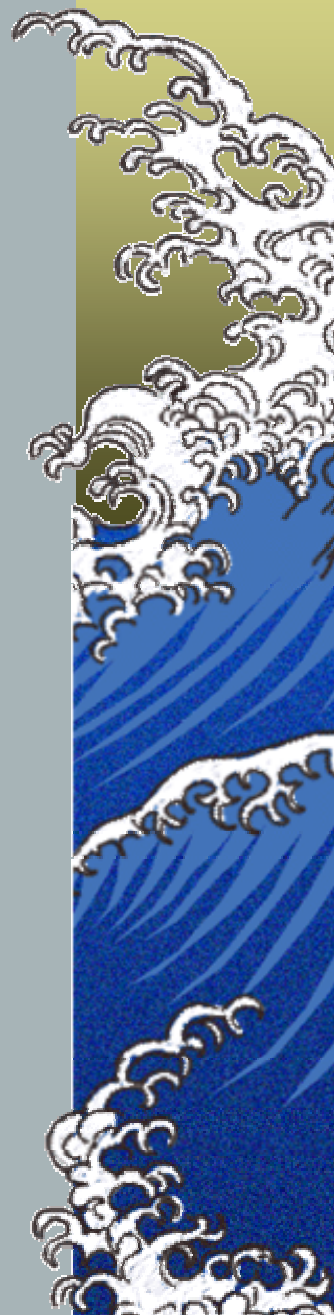
RCM (40 km gridpt side)



LINKS BETWEEN GLOBAL and REGIONAL CLIMATE MODELS

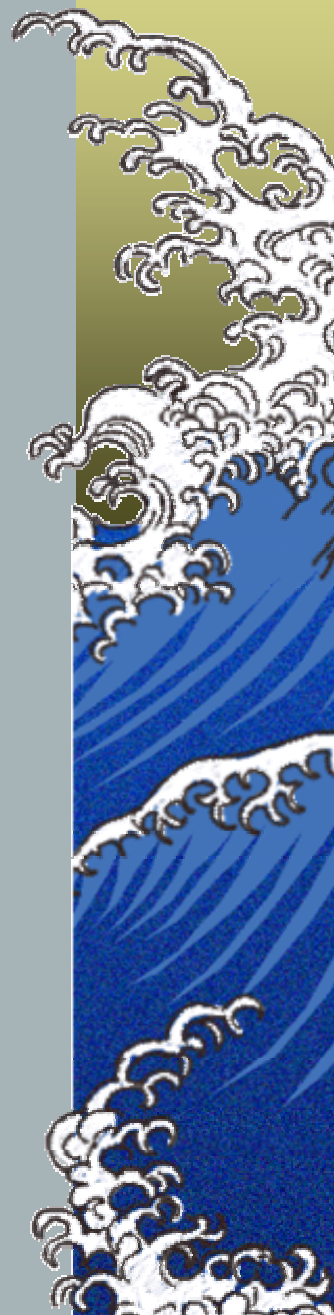


FUTURE CLIMATE SCENARIOS FOR CALIFORNIA: MODEL RESULTS AND POSSIBLE IMPACTS



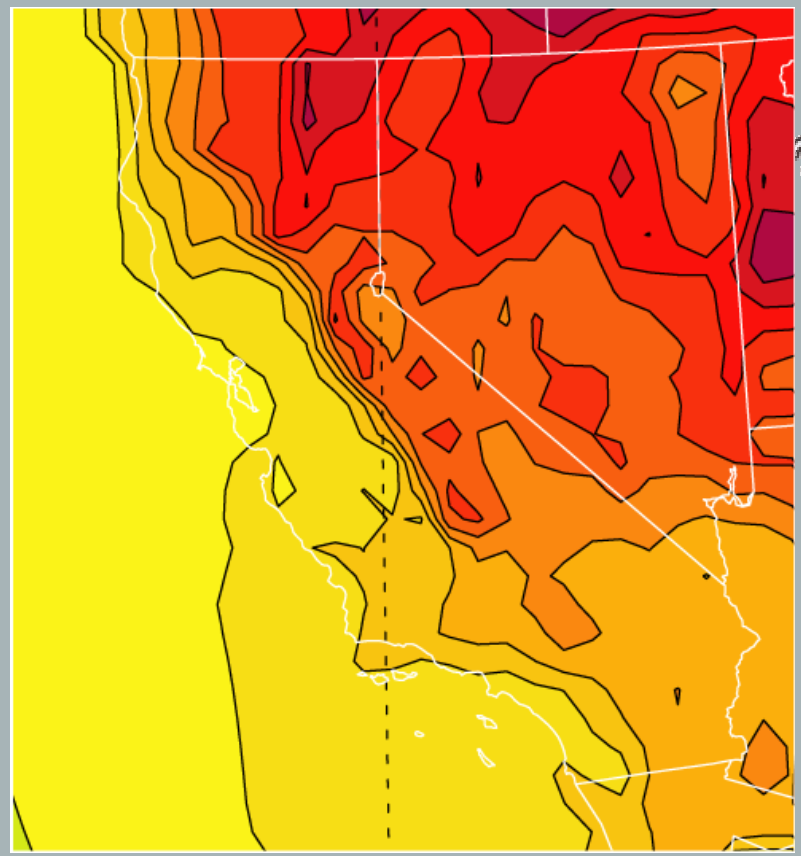
HOW WILL CALIFORNIA'S CLIMATE RESPOND TO A DOUBLING OF ATMOSPHERIC CO_2?

- *In an initial study, we carried out two modeling studies, in which we calculated climate with 1xCO_2 and 2xCO_2*
- *Each model case was carried out for 15 years (+3 removed for spinup)*
- *We show results in terms of how different climate aspects will respond to 2xCO_2*



ANNUAL TEMPERATURE RESPONSE to 2xCO_2

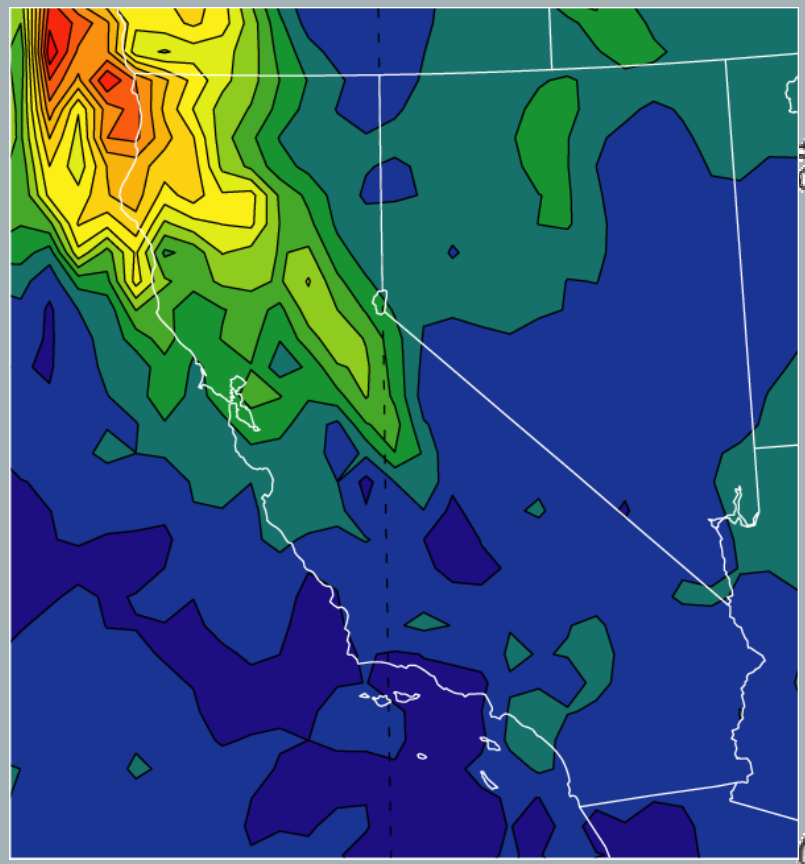
- *Average annual temperature increases everywhere in California*
- *Temperature increases are greatest inland*



Snyder et al., 2002

ANNUAL PRECIPITATION RESPONSE to 2xCO_2

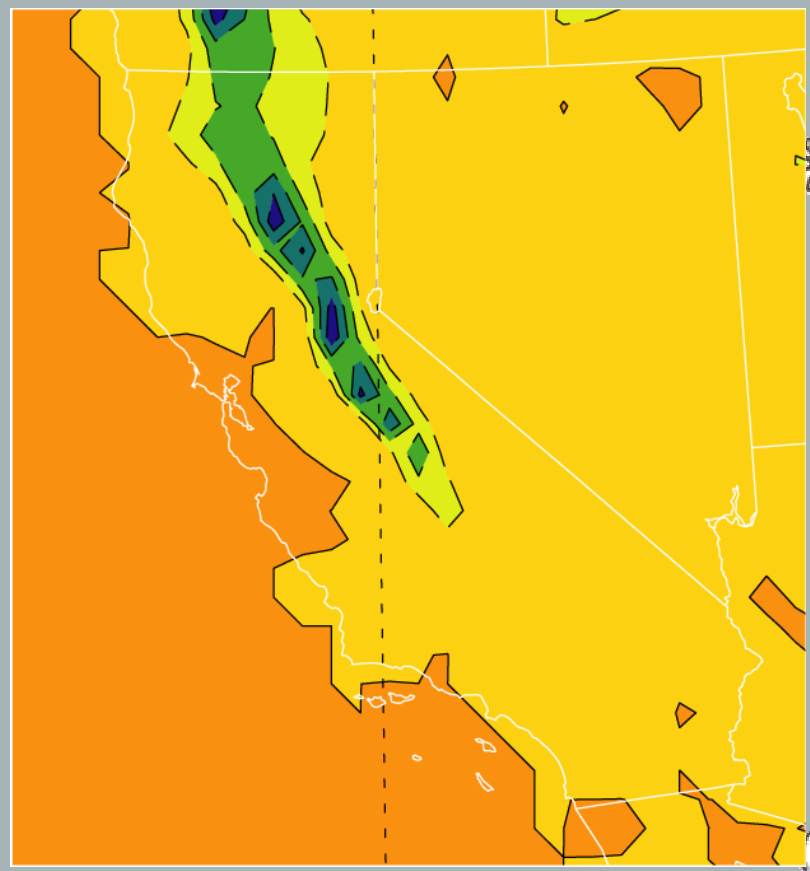
- *On a yearly average basis, precipitation increases slightly in the northern third of the state and stays the same or decreases across the rest of the state*



Snyder et al., 2002

ANNUAL SNOW ACCUMULATION RESPONSE TO $2xCO_2$

- *Snowpack is reduced everywhere in the state on an annual and monthly basis*
- *Snowpack is reduced by as much or more than 60%*



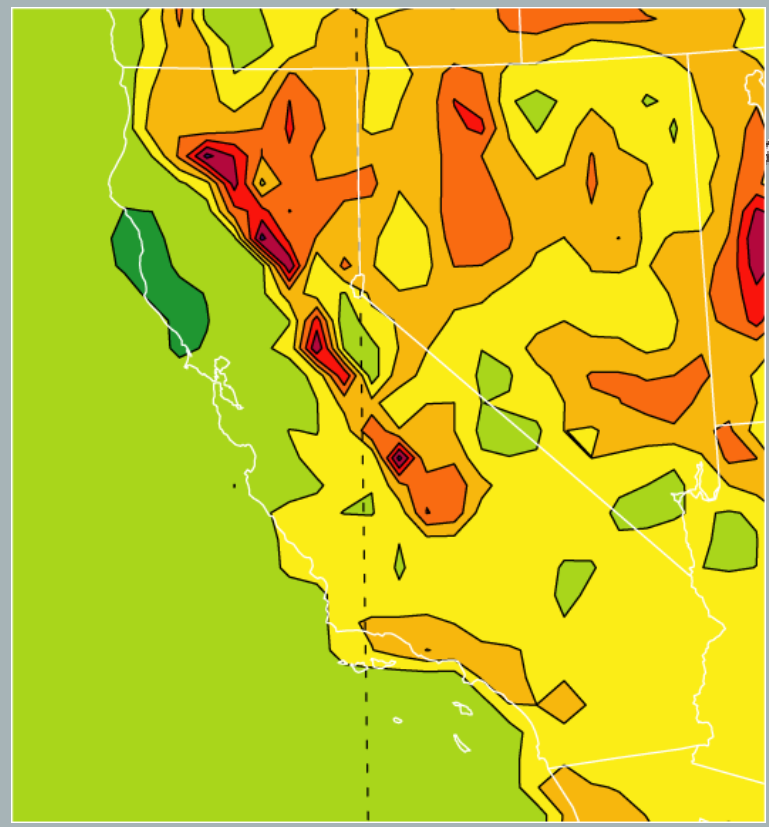
Cm water equiv

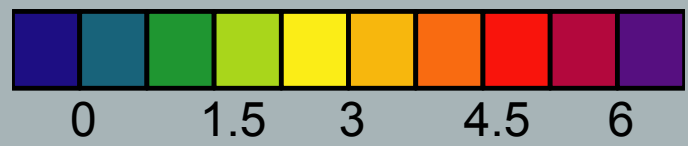
-12 -6 0 6

Snyder et al., 2002

AVERAGE APRIL TEMPERATURE RESPONSE to $2xCO_2$

- *Temperature increases everywhere in the state, with largest increases (> 10°F) in high elevation regions*
- *Monthly changes show much more variation than annual mean results*

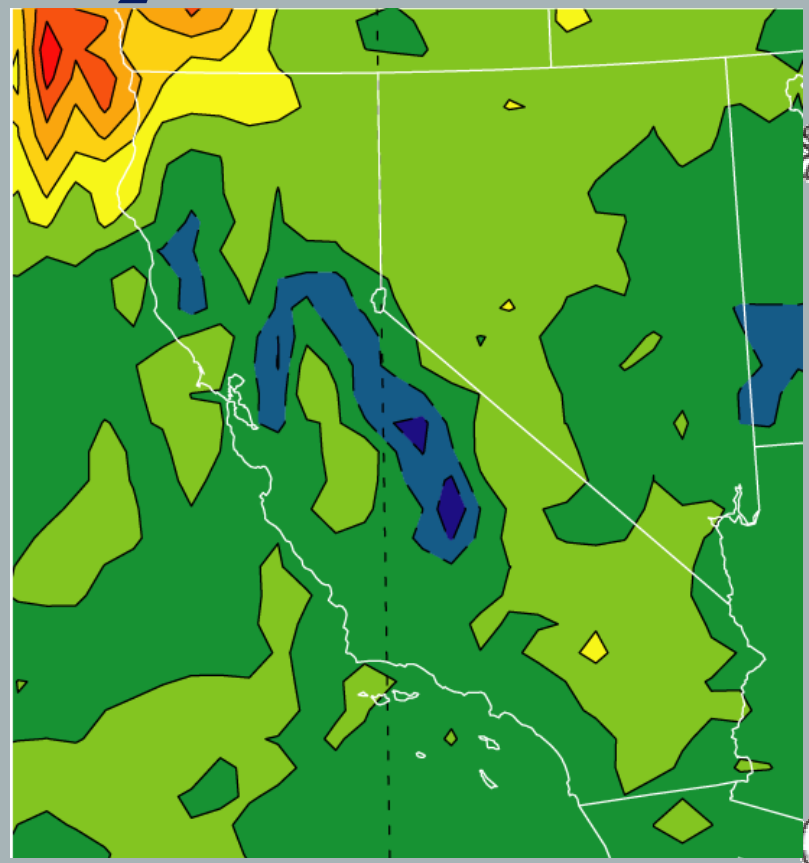


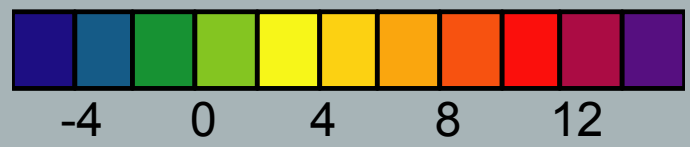


Snyder et al., 2002

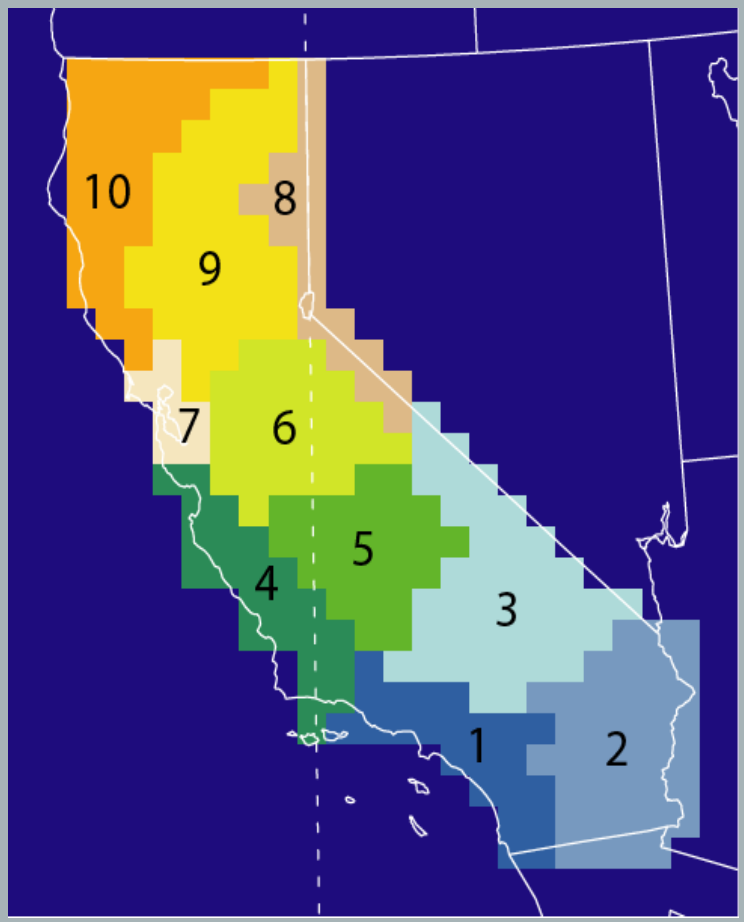
AVERAGE APRIL PRECIPITATION RESPONSE to $2xCO_2$

- *Unlike the annual average, April precipitation decreases in the central portion of California*
- *The annual estimate is insufficient to capture the full response or to plan for future changes*





CLIMATE RESPONSES to $2xCO_2$ by HYDROLOGIC BASIN

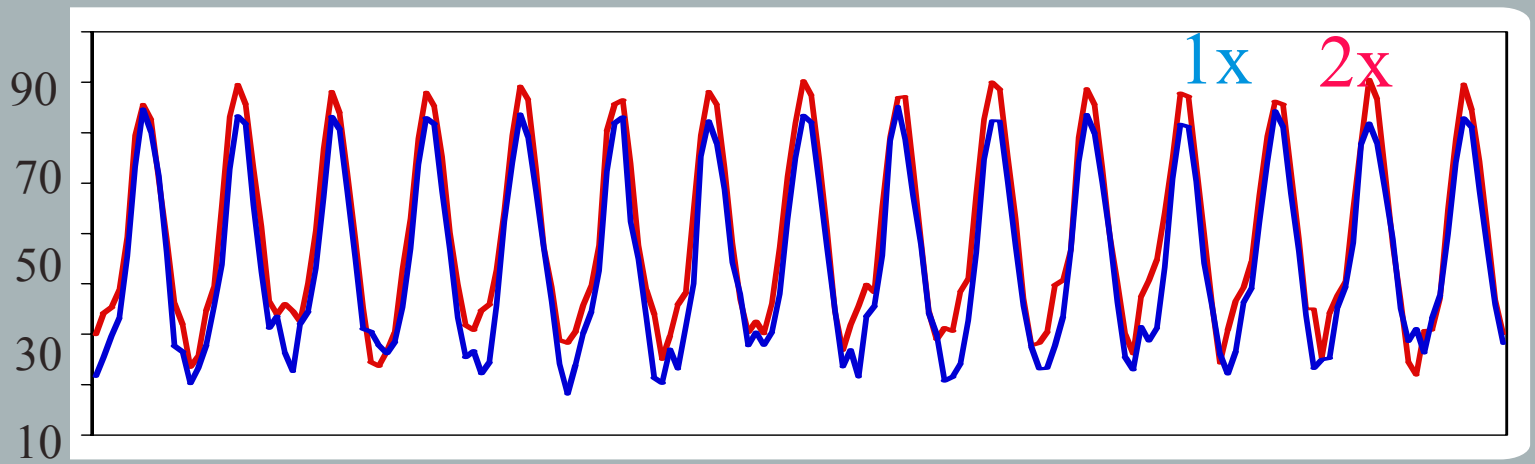


Snyder et al., 2004

Summary of Temperature Results

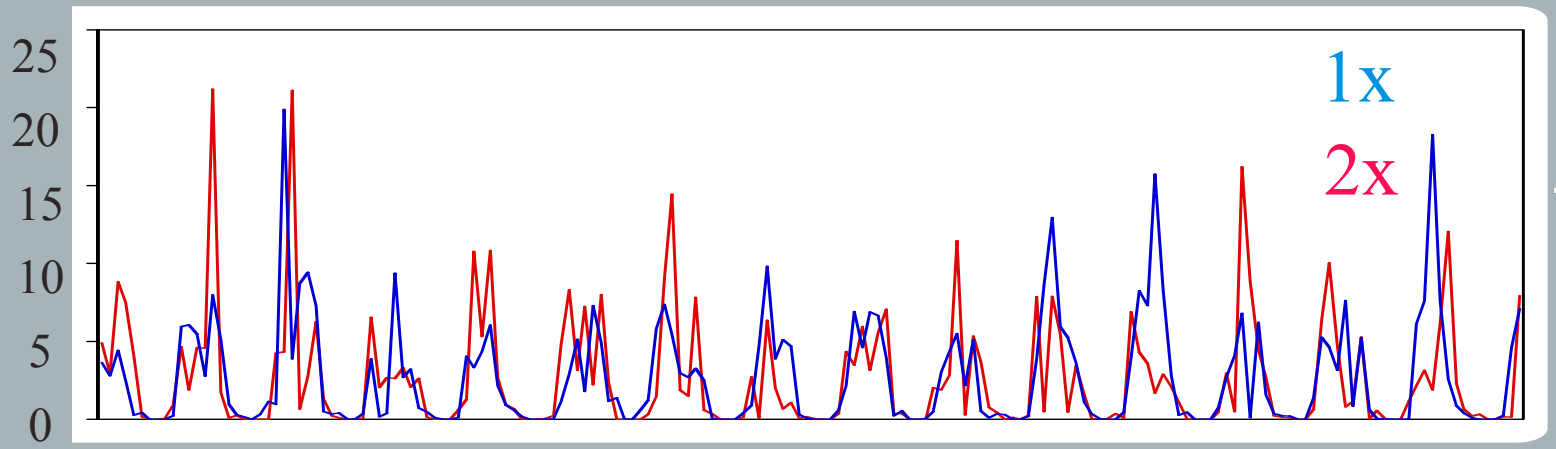
•Hydrologic Region	•Annual Average Temperature Change (°C)	•Greatest Monthly Temperature Change
•South Coast	•+2.10	•+3.19 (May)
•CO River	•+2.35	•+3.33 (Sep)
•S. Lahontan	•+2.56	•+3.96 (Feb)
•Central Coast	•+1.92	•+2.88 (Jun)
•Tulare Lake	•+2.38	•+3.55 (Jun)
•San Joaquin	•+2.36	•+4.08 (Jun)
•SF Bay	•+1.72	•+3.18 (Jun)
•N. Lahontan	•+3.12	•+5.02 (Feb)
•Sacramento	•+2.82	•+4.11 (Jun)
•North Coast	•+2.39	•+3.60 (Feb)

Sacramento River Basin Temperature Response to 2xCO_2



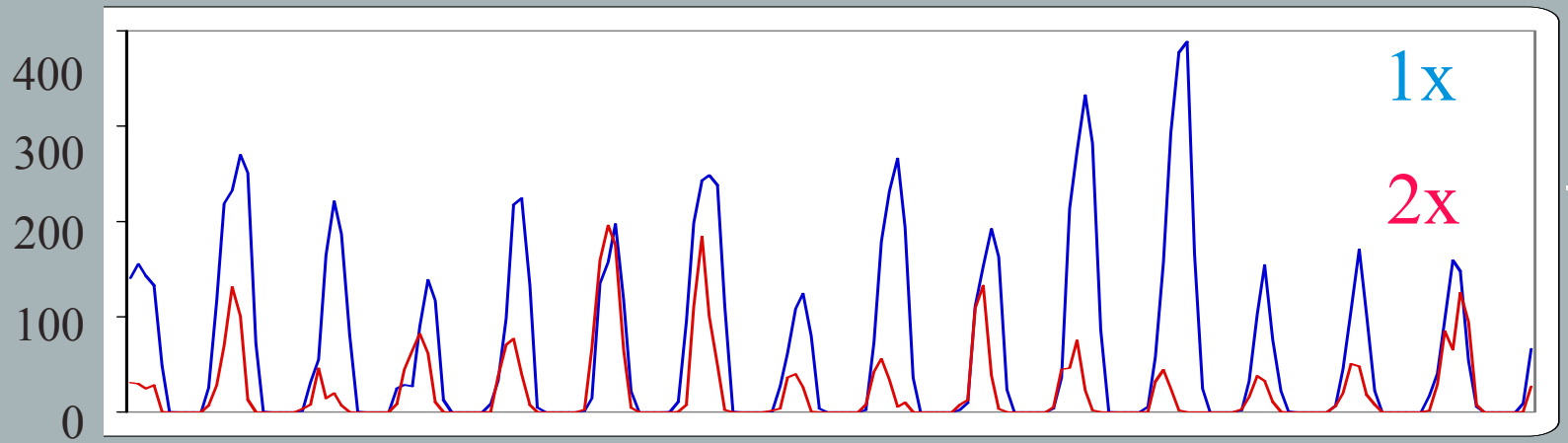
- *Temperature increases are greatest in the winter, with substantial increases also occurring in the spring and summer*

Sacramento River Basin Precipitation Response to $2xCO_2$



- *Total precipitation is reduced*
- *The rain season is truncated in both autumn and spring seasons*

Sacramento River Basin Snow Accumulation Response to $2xCO_2$



- *Total snow accumulation is reduced*
- *The snow year is shortened substantially due to reduction of spring snowfalls*

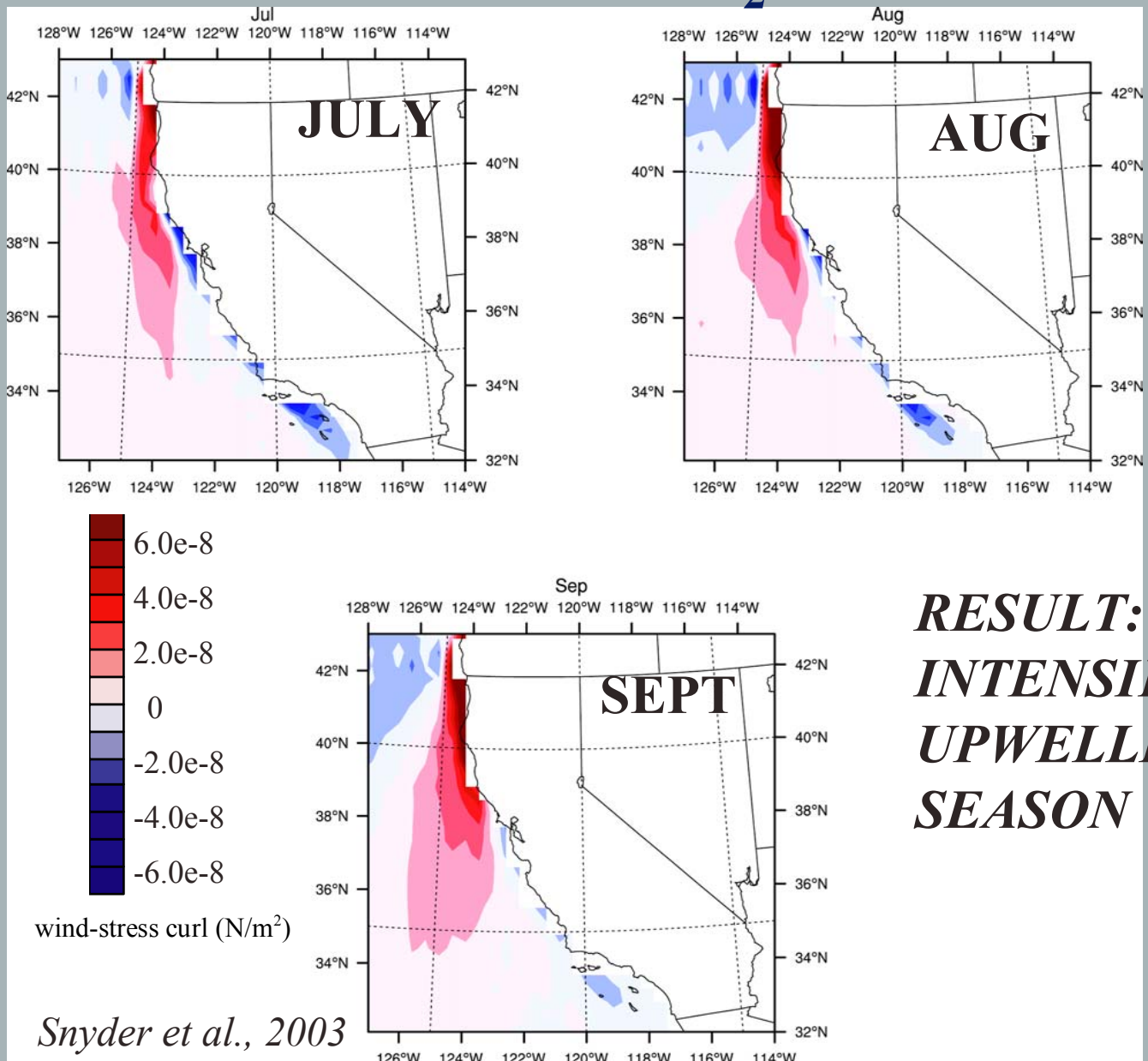
California Current upwelling response to future pCO_2 increases & climate change

- *Observations suggest that wind-driven upwelling along the coast of California (western North America) has been increasing over the past 30 years*
- *Hypothesized cause for the increase is greenhouse gas forcing (leading to increased land-sea thermal contrast and intensified wind strength)*

Upwelling Calculation

- *Generate monthly average surface wind fields for each case*
- *Calculate wind stress curl (Ortiz et al., 1997)*
- *RegCM2.5 accurately reproduces the modern seasonality and seasonal contrast of wind stress curl along the California Current*

WIND-DRIVEN UPWELLING RESPONSE to 2xCO_2

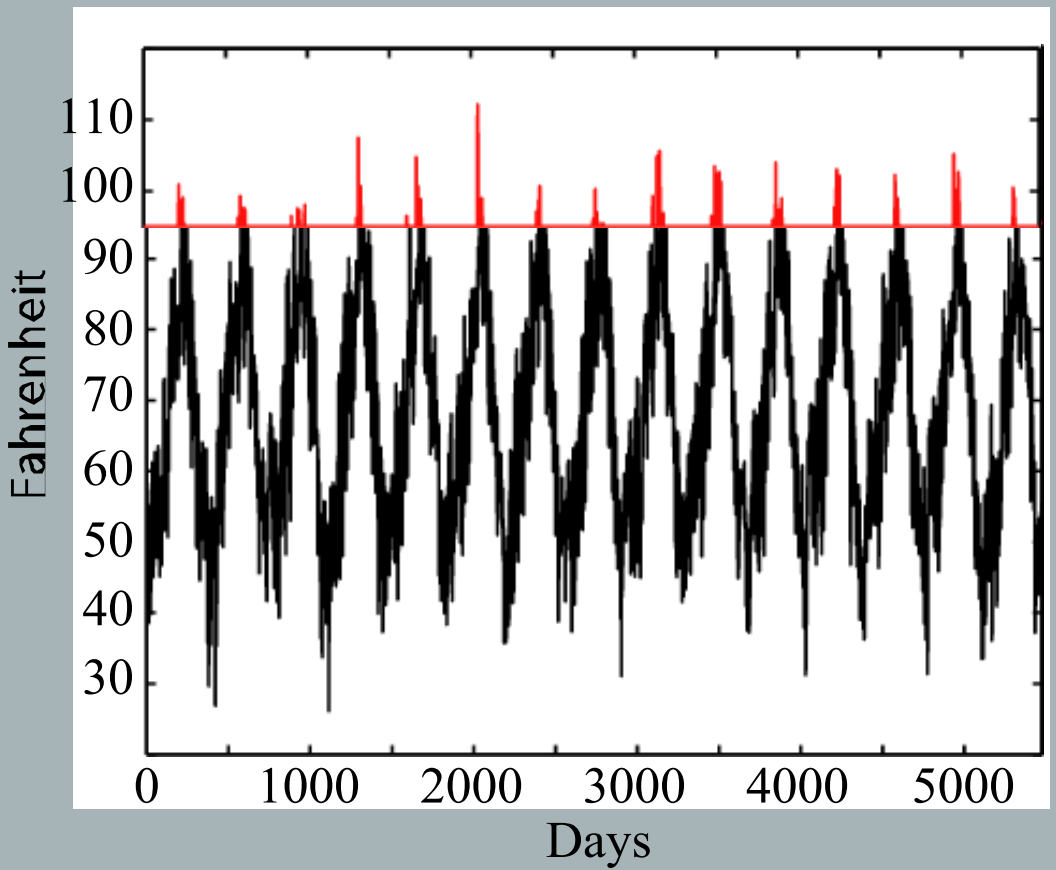


Snyder et al., 2003

RESULT: INTENSIFIED UPWELLING SEASON

Climate Extremes: Response of Daily Temperature to $2xCO_2$

$2xCO_2$ Max Temperature - L.A. Region

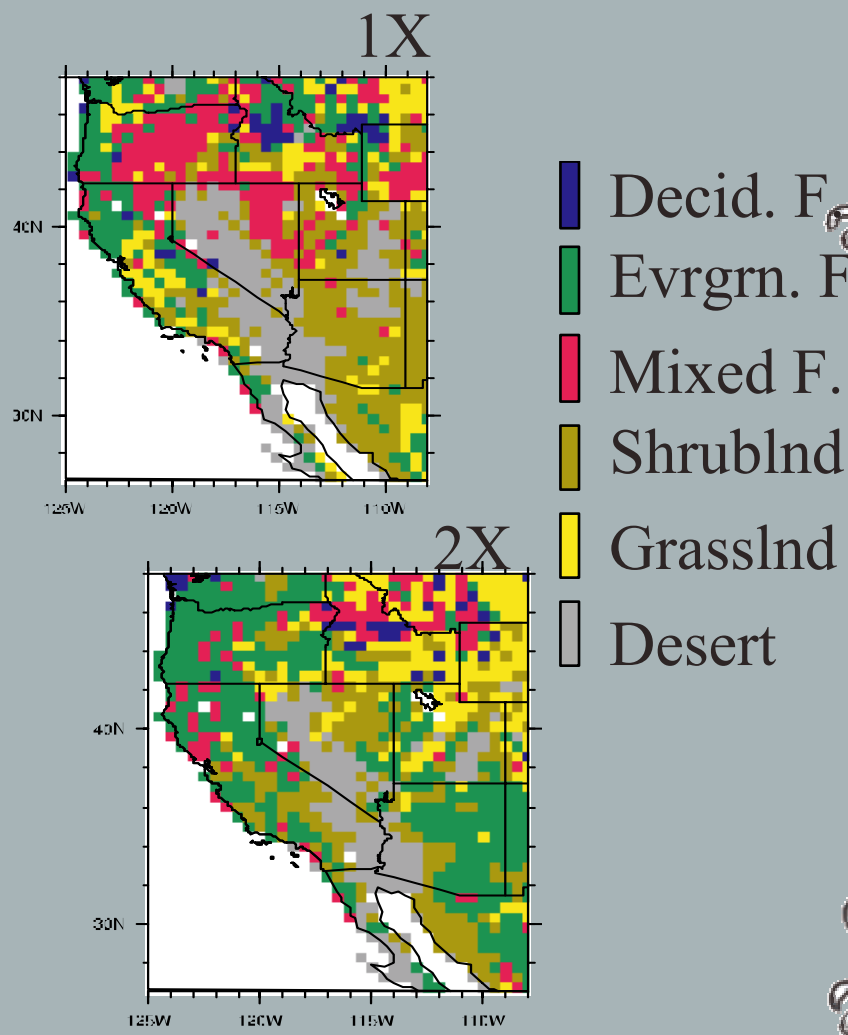


Days/yr with temperature > 95° (F) double in L. A. and quadruple in San Francisco

Bell, Sloan & Snyder, 2003

Terrestrial Biome Responses to 2xCO_2

- *Increased CO_2 drives changes in biome distributions via both climate and physiological effects*
- *Mixed forests and grasslands are reduced, shrublands and evergreen forests expand with 2xCO_2*

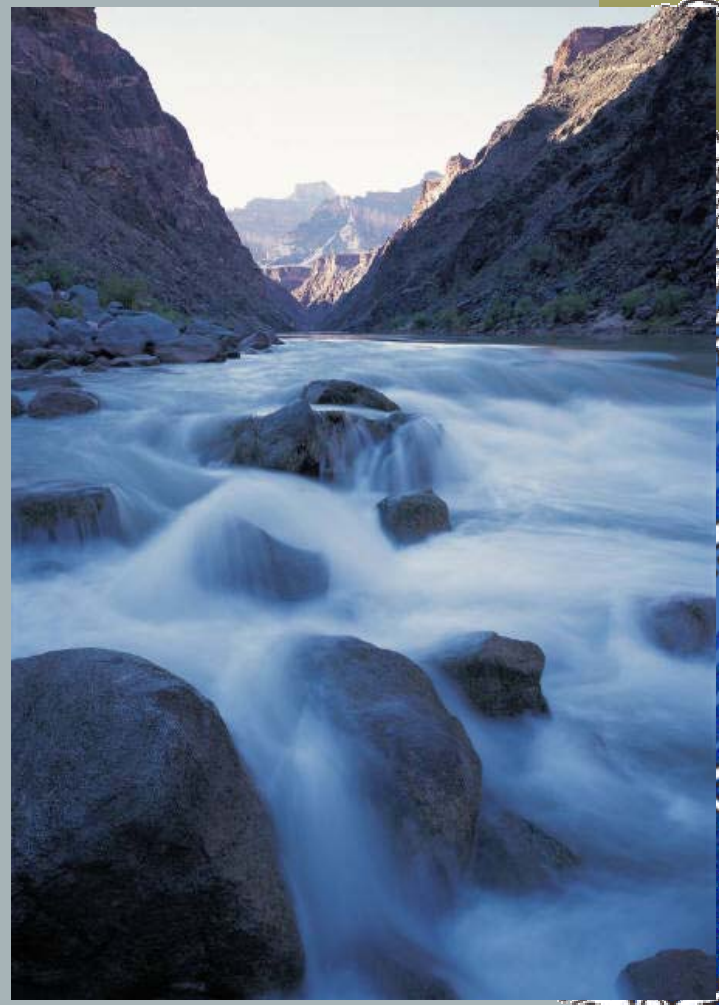


Diffenbaugh et al., 2003

IMPACTS of FUTURE CLIMATE CHANGE UPON CALIFORNIA

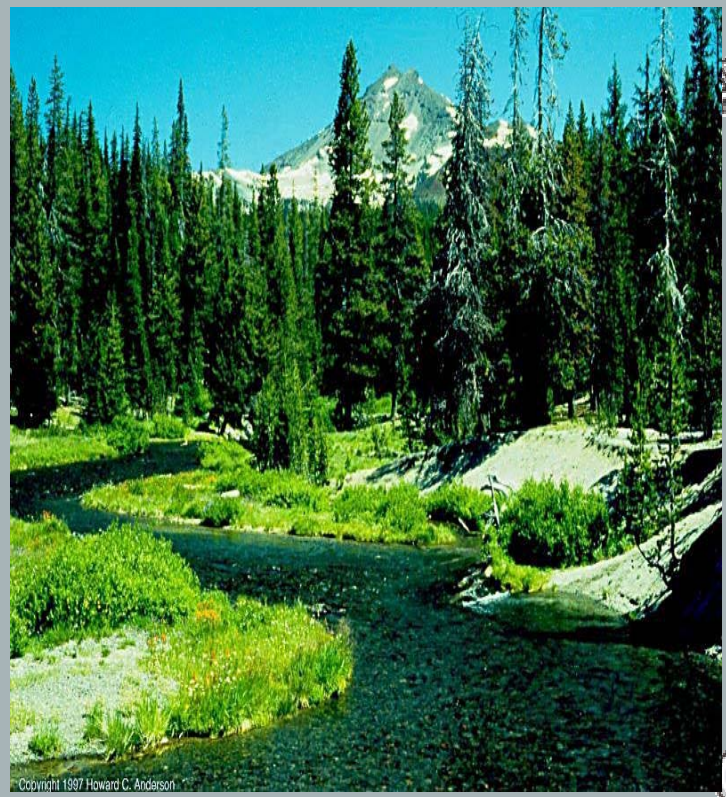
FUTURE CLIMATE IMPACTS: CALIFORNIA WATER

- *Total water availability is likely to be reduced*
- *Timing of water delivery will be disrupted, as snow volume and the snow year decreases and the rain season is shortened*
- *Storage and delivery of water throughout the state will be challenged*



FUTURE CLIMATE IMPACTS: CALIFORNIA WATER

- *Snowmelt runoff will decrease and will occur earlier in the spring with less flow in the summer*
- *Changes in duration of water year will impact aquatic biota*
- *Changes in runoff timing and volume will impact river, lake, and coastal marine ecosystems*



FUTURE CLIMATE IMPACTS: CALIFORNIA WATER

- *Increased air temperature and decreased snowmelt runoff will lead to warming of rivers and lakes*
- *Changes in water temperature in rivers, lakes, and oceans will impact biota*

FUTURE CLIMATE IMPACTS: TERRESTRIAL SYSTEMS

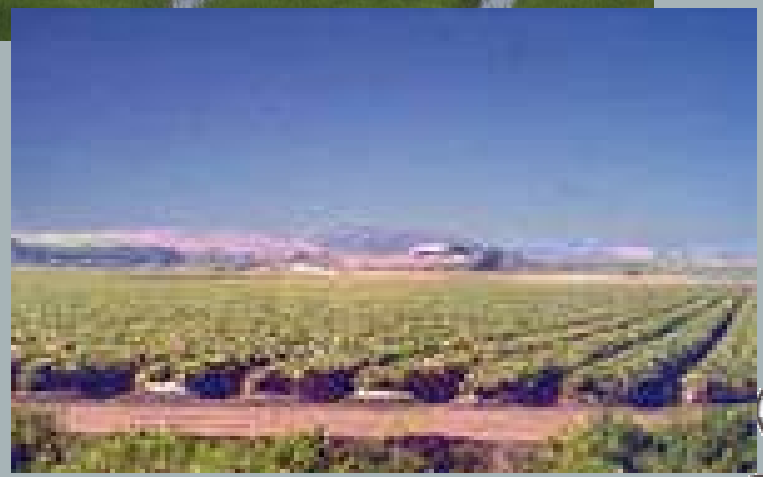
- *Model results indicate extreme spring and summer warming at high elevations; how will ecosystems in these regions survive such changes?*
- *Model results suggest major changes in temperature, rain and snow regimes; how will ecosystems adapt?*

FUTURE CLIMATE IMPACTS: COASTAL SYSTEMS

- *Intensified upwelling and a shift in its peak season may impact:*
- *coastal marine species,*
- *fog,*
- *coastal terrestrial species*

FUTURE CLIMATE IMPACTS: AGRICULTURE

- *Agriculture may have to adapt to changing temperatures and water availability*
- *Crops may have to be adjusted*



FUTURE CLIMATE IMPACTS: HEALTH and SAFETY

- *Diseases that are temperature dependent may become more widespread*
- *Number of severely hot days will increase*
- *Fire potential will likely increase*

This research would not be possible without the UCSC Climate Change and Impacts Laboratory and the following research team members:

Jason Bell
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Noah Diffenbaugh, Ph.D

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